higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

**NATIONAL CERTIFICATE**

# CHEMICAL PLANT OPERATION N5

(8050015)

**5 August 2021 (X-paper)**
**09:00–12:00**

**Drawing instruments and nonprogrammable calculators may be used.**

**This question paper consists of 4 pages, 1 periodic table, 1steam table and 2 information sheets.**

195Q1G2105

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# DEPARTMENT OF HIGHER EDUCATION AND TRAINING
# REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE
CHEMICAL PLANT OPERATION N5
TIME: 3 HOURS
MARKS: 100

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**INSTRUCTIONS AND INFORMATION**

1. Answer all the questions.
2. Read all the questions carefully.
3. Number the answers according to the numbering system used in this question paper.
4. Start each question on a new page.
5. Only use a black or blue pen.
6. Write neatly and legibly.

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## QUESTION 1

Complete the following sentences by filling in the missing word or words. Write only the word or words next to the question number (1.1–1.10) in the ANSWER BOOK.

1.1 … is the form or manifestation of energy that flows from one object to another.

1.2 Calorie refers to the amount of … to raise the temperature of one gram of water from 14,5 °C to 15,5 °C.

1.3 Kopp's rule states that the total heat capacity of a compound is approximately equal to the sum of the heat capacities of the …

1.4 If steam contains … suspended in it, it is called wet steam.

1.5 In an impulse turbine, the entire available … from supply to exhaust occurs across the nozzles.

1.6 In axial-flow turbines the steam flow is … to the turbine axis.

1.7 When burners are burning with a/an …, it indicates that complete combustion has taken place.

1.8 In cyclones, the incoming dust-laden air receives a/an … on entrance to the cylinder.

1.9 Sulphuric acid and salt are roasted in a furnace to form … and sodium sulphate.

1.10 Tumbling mixers are used for dense solids in liquids and …

(10 × 2) **[20]**

## QUESTION 2

2.1 Superheated steam at 500 °C and 4 000 kPa is concentrated at 100 kPa.

Determine the heat available for the heating process.

**NOTE**: Accept that the steam $C_p$ = 1,97 kJ/kg.K. (5)

2.2 Write short notes on the following types of steam turbines:

2.2.1 Curtis turbine

2.2.2 Reaction turbine

(2 × 5) (10)
**[15]**

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## QUESTION 3

3.1 Draw a labelled diagram of the closed-cycle gas turbine system. (6)

3.2 Briefly explain the operation of the horizontal rotating-cup atomising oil burner and draw a labelled diagram of this burner. (4 + 5) (9)

3.3 Write short notes on the following mixers:

3.3.1 Ribbon mixer

3.3.2 Muller mixer

3.3.3 Double-arm kneader

(3 × 5) (15)
**[30]**

## QUESTION 4

4.1 The analysis of the off-gas (effluent) from a burner using $C_4H_{10}$ is as follows:

$N_2$ = 75 mol%; $O_2$ = 13 mol%; $CO_2$ = 7 mol% and $H_2O$ = 5 mol%.

Determine the ratio of moles of air to the moles of $C_4H_{10}$ used in the burner. (10)

4.2 What are the FOUR conditions to be considered when maximising the chemical conversion of sulphur dioxide to sulphur trioxide? (4)

4.3 Discuss the operation of a cyclone. (6)
**[20]**

## QUESTION 5

5.1 Describe *dry saturated steam*. (3)

5.2 Draw a fully labelled diagram of the production of 60% concentrated nitric acid from ammonia. (12)
**[15]**

**TOTAL: 100**

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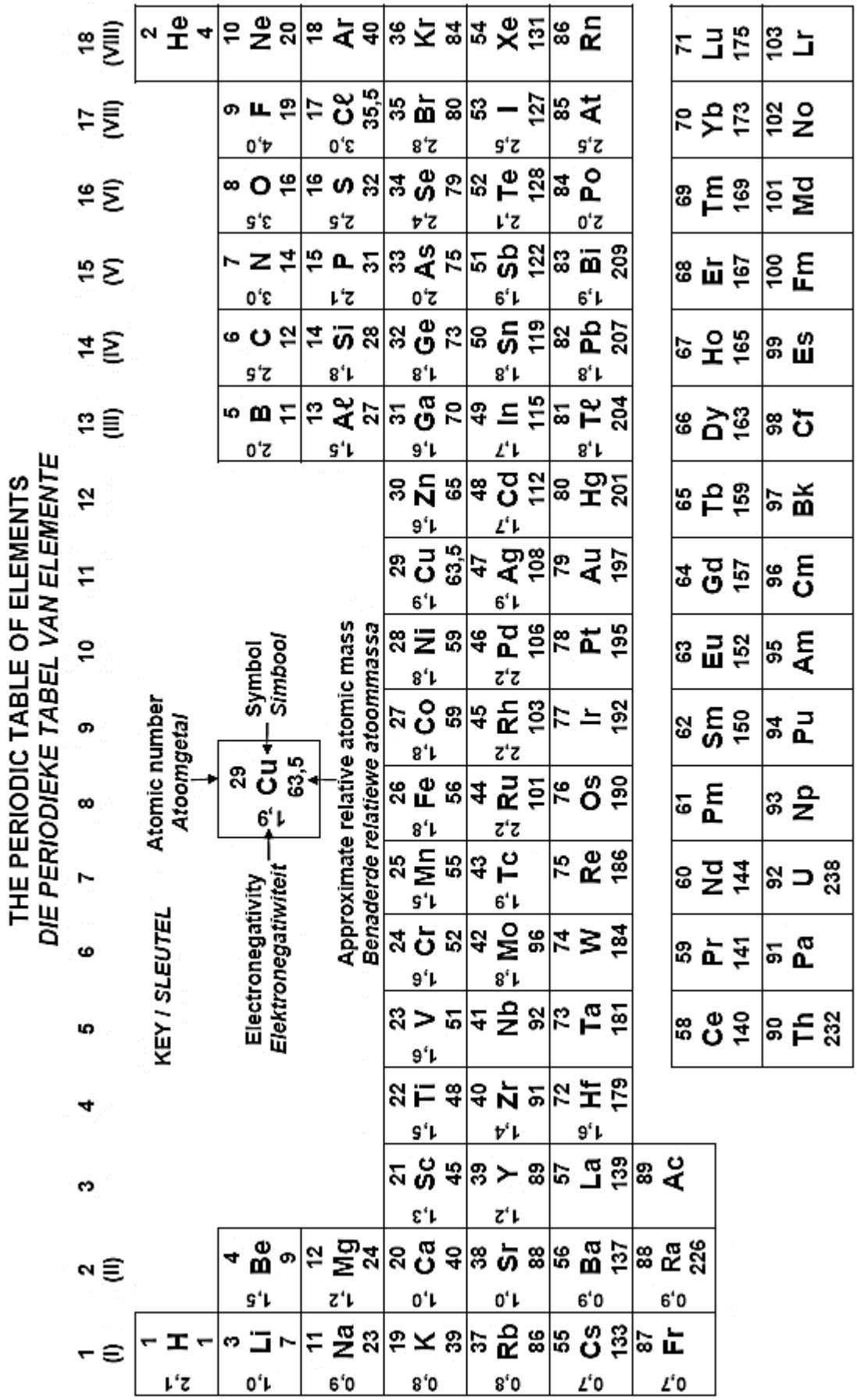
**PERIODIC TABLE**

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## STEAM TABLE

| p | $t_s$ | $v_g$ | $h_f$ | $h_{fg}$ | $h_g$ | $s_f$ | $s_g$ | p | $t_s$ | $v_g$ | $h_f$ | $h_{fg}$ | $h_g$ | $s_f$ | $s_g$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| kPa | °C | $m^3/kg$ | kJ/kg | kJ/kg | kJ/kg | kJ/kg. K | kJ/kg. K | kPa | °C | $m^3/kg$ | kJ/kg | kJ/kg | kJ/kg | kJ/kg. K | kJ/kg. K |
| 1,0 | 7,0 | 129,20 | 29 | 2 485 | 2 514 | 0,106 | 8,977 | 75 | 91,8 | 2,217 | 385 | 2 279 | 2 664 | 1,213 | 7,457 |
| 1,5 | 13,0 | 87,98 | 55 | 2 471 | 2 526 | 0,196 | 8,829 | 80 | 93,5 | 2,087 | 392 | 2 274 | 2 666 | 1,233 | 7,435 |
| 2,0 | 17,5 | 67,01 | 74 | 2 460 | 2 534 | 0,261 | 8,725 | 85 | 95,2 | 1,972 | 399 | 2 270 | 2 669 | 1,252 | 7,415 |
| 2,5 | 21,1 | 54,26 | 89 | 2 452 | 2 541 | 0,312 | 8,644 | 90 | 96,7 | 1,869 | 405 | 2 266 | 2 671 | 1,270 | 7,395 |
| 3,0 | 24,1 | 45,67 | 101 | 2 445 | 2 546 | 0,354 | 8,579 | 95 | 98,2 | 1,777 | 412 | 2 262 | 2 674 | 1,287 | 7,377 |
| 3,5 | 26,7 | 39,48 | 112 | 2 439 | 2 551 | 0,391 | 8,523 | 100 | 99,6 | 1,694 | 418 | 2 258 | 2 676 | 1,303 | 7,360 |
| 4,0 | 29,0 | 34,80 | 121 | 2 433 | 2 554 | 0,423 | 8,476 | 110 | 102,3 | 1,549 | 429 | 2 251 | 2 680 | 1,333 | 7,328 |
| 4,5 | 31,0 | 31,14 | 130 | 2 428 | 2 558 | 0,451 | 8,434 | 120 | 104,8 | 1,428 | 439 | 2 244 | 2 683 | 1,361 | 7,300 |
| 5,0 | 32,9 | 28,19 | 138 | 2 424 | 2 562 | 0,476 | 8,396 | 130 | 107,1 | 1,325 | 449 | 2 238 | 2 687 | 1,387 | 7,272 |
| 5,5 | 34,6 | 25,77 | 145 | 2 420 | 2 565 | 0,500 | 8,362 | 140 | 109,3 | 1,236 | 458 | 2 232 | 2 690 | 1,411 | 7,247 |
| 6,0 | 36,2 | 23,74 | 152 | 2 416 | 2 568 | 0,521 | 8,331 | 150 | 111,4 | 1,159 | 467 | 2 226 | 2 693 | 1,434 | 7,223 |
| 6,5 | 37,7 | 22,02 | 158 | 2 413 | 2 571 | 0,541 | 8,303 | 160 | 113,3 | 1,091 | 475 | 2 221 | 2 696 | 1,455 | 7,202 |
| 7,0 | 39,0 | 20,53 | 163 | 2 410 | 2 573 | 0,559 | 8,277 | 170 | 115,2 | 1,031 | 483 | 2 216 | 2 699 | 1,475 | 7,181 |
| 7,5 | 40,3 | 19,24 | 169 | 2 406 | 2 575 | 0,576 | 8,252 | 180 | 116,9 | 0,977 2 | 491 | 2 211 | 2 702 | 1,494 | 7,162 |
| 8,0 | 41,6 | 18,10 | 174 | 2 403 | 2 577 | 0,593 | 8,230 | 190 | 118,6 | 0,929 0 | 498 | 2 206 | 2 704 | 1,513 | 7,144 |
| 8,5 | 42,7 | 17,10 | 179 | 2 401 | 2 580 | 0,608 | 8,208 | 200 | 120,2 | 0,885 4 | 505 | 2 202 | 2 707 | 1,530 | 7,127 |
| 9,0 | 43,8 | 16,20 | 183 | 2 398 | 2 581 | 0,622 | 8,188 | 210 | 121,8 | 0,845 9 | 511 | 2 197 | 2 708 | 1,547 | 7,111 |
| 9,5 | 44,8 | 15,40 | 188 | 2 395 | 2 583 | 0,636 | 8,169 | 220 | 123,3 | 0,809 8 | 518 | 2 193 | 2 711 | 1,563 | 7,095 |
| 10 | 45,8 | 14,67 | 192 | 2 393 | 2 585 | 0,649 | 8,151 | 230 | 124,7 | 0,776 8 | 524 | 2 189 | 2 713 | 1,578 | 7,080 |
| 11 | 47,7 | 13,42 | 200 | 2 388 | 2 588 | 0,674 | 8,118 | 240 | 126,1 | 0,746 5 | 530 | 2 185 | 2 715 | 1,593 | 7,066 |
| 12 | 49,5 | 12,36 | 207 | 2 384 | 2 591 | 0,698 | 8,087 | 250 | 127,4 | 0,718 4 | 535 | 2 181 | 2 716 | 1,607 | 7,052 |
| 13 | 51,1 | 11,47 | 214 | 2 380 | 2 594 | 0,717 | 8,059 | 260 | 128,7 | 0,692 5 | 541 | 2 177 | 2 718 | 1,621 | 7,039 |
| 14 | 52,6 | 10,69 | 220 | 2 377 | 2 597 | 0,737 | 8,033 | 270 | 130,0 | 0,668 4 | 546 | 2 174 | 2 720 | 1,634 | 7,026 |
| 15 | 54,0 | 10,02 | 226 | 2 373 | 2 599 | 0,755 | 8,009 | 280 | 131,2 | 0,646 0 | 551 | 2 170 | 2 721 | 1,647 | 7,014 |
| 16 | 55,3 | 9,433 | 232 | 2 370 | 2 602 | 0,772 | 7,987 | 290 | 132,4 | 0,625 1 | 557 | 2 167 | 2 724 | 1,660 | 7,002 |
| 17 | 56,6 | 8,911 | 237 | 2 367 | 2 604 | 0,788 | 7,966 | 300 | 133,5 | 0,605 6 | 561 | 2 163 | 2 724 | 1,672 | 6,991 |
| 18 | 57,8 | 8,445 | 242 | 2 364 | 2 606 | 0,804 | 7,946 | 310 | 134,7 | 0,587 2 | 566 | 2 160 | 2 726 | 1,683 | 6,980 |
| 19 | 59,0 | 8,027 | 247 | 2 361 | 2 608 | 0,818 | 7,927 | 320 | 135,8 | 0,570 0 | 571 | 2 157 | 2 728 | 1,695 | 6,969 |
| 20 | 60,1 | 7,650 | 252 | 2 358 | 2 610 | 0,832 | 7,909 | 330 | 136,8 | 0,553 8 | 576 | 2 154 | 2 730 | 1,706 | 6,959 |
| 21 | 61,1 | 7,307 | 256 | 2 356 | 2 612 | 0,845 | 7,893 | 340 | 137,9 | 0,538 5 | 580 | 2 150 | 2 730 | 1,717 | 6,949 |
| 22 | 62,2 | 6,995 | 260 | 2 353 | 2 613 | 0,858 | 7,876 | 350 | 138,9 | 0,524 0 | 584 | 2 147 | 2 731 | 1,727 | 6,939 |
| 23 | 63,1 | 6,709 | 264 | 2 351 | 2 615 | 0,870 | 7,861 | 360 | 139,9 | 0,510 3 | 589 | 2 144 | 2 733 | 1,738 | 6,930 |
| 24 | 64,1 | 6,447 | 268 | 2 349 | 2 617 | 0,882 | 7,846 | 370 | 140,8 | 0,497 4 | 593 | 2 141 | 2 734 | 1,748 | 6,921 |
| 25 | 65,0 | 6,204 | 272 | 2 346 | 2 618 | 0,893 | 7,832 | 380 | 141,8 | 0,485 1 | 597 | 2 139 | 2 736 | 1,757 | 6,912 |
| 26 | 65,9 | 5,980 | 276 | 2 344 | 2 620 | 0,904 | 7,819 | 390 | 142,7 | 0,473 4 | 601 | 2 136 | 2 737 | 1,767 | 6,903 |
| 27 | 66,7 | 5,772 | 279 | 2 342 | 2 621 | 0,915 | 7,806 | 400 | 143,6 | 0,462 2 | 605 | 2 133 | 2 738 | 1,776 | 6,894 |
| 28 | 67,6 | 5,579 | 283 | 2 340 | 2 623 | 0,925 | 7,793 | 410 | 144,5 | 0,451 6 | 609 | 2 130 | 2 739 | 1,786 | 6,886 |
| 29 | 68,3 | 5,398 | 286 | 2 338 | 2 624 | 0,935 | 7,781 | 420 | 145,4 | 0,441 5 | 612 | 2 128 | 2 740 | 1,795 | 6,878 |
| 30 | 69,1 | 5,229 | 289 | 2 336 | 2 625 | 0,944 | 7,770 | 430 | 146,3 | 0,431 8 | 616 | 2 125 | 2 741 | 1,803 | 6,870 |
| 32 | 70,6 | 4,922 | 296 | 2 332 | 2 628 | 0,962 | 7,747 | 440 | 147,1 | 0,422 6 | 620 | 2 122 | 2 742 | 1,812 | 6,862 |
| 34 | 72,0 | 4,650 | 302 | 2 329 | 2 631 | 0,980 | 7,727 | 450 | 147,9 | 0,413 8 | 624 | 2 120 | 2 744 | 1,820 | 6,855 |
| 36 | 73,4 | 4,408 | 307 | 2 326 | 2 633 | 0,996 | 7,707 | 460 | 148,7 | 0,405 3 | 627 | 2 117 | 2 744 | 1,829 | 6,847 |
| 38 | 74,7 | 4,190 | 313 | 2 322 | 2 635 | 1,011 | 7,688 | 470 | 149,5 | 0,397 2 | 630 | 2 115 | 2 745 | 1,837 | 6,840 |
| 40 | 75,9 | 3,993 | 318 | 2 319 | 2 637 | 1,026 | 7,671 | 480 | 150,3 | 0,389 4 | 634 | 2 112 | 2 746 | 1,845 | 6,833 |
| 45 | 78,7 | 3,576 | 330 | 2 312 | 2 642 | 1,060 | 7,631 | 490 | 151,1 | 0,381 9 | 637 | 2 110 | 2 747 | 1,853 | 6,826 |
| 50 | 81,4 | 3,240 | 341 | 2 305 | 2 646 | 1,091 | 7,595 | 500 | 151,8 | 0,374 7 | 640 | 2 107 | 2 747 | 1,860 | 6,819 |
| 55 | 83,7 | 2,964 | 351 | 2 299 | 2 650 | 1,119 | 7,562 | 520 | 153,3 | 0,361 1 | 647 | 2 103 | 2 750 | 1,875 | 6,806 |
| 60 | 86,0 | 2,732 | 360 | 2 294 | 2 654 | 1,145 | 7,533 | 540 | 154,8 | 0,348 5 | 653 | 2 098 | 2 751 | 1,890 | 6,793 |
| 65 | 88,0 | 2,535 | 369 | 2 288 | 2 657 | 1,170 | 7,506 | 560 | 156,2 | 0,336 7 | 659 | 2 094 | 2 753 | 1,904 | 6,781 |
| 70 | 90,0 | 2,365 | 377 | 2 283 | 2 660 | 1,192 | 7,480 | 580 | 157,5 | 0,325 7 | 665 | 2 089 | 2 754 | 1,918 | 6,769 |

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**INFORMATION SHEET 1**

Mean molar heat capacities of gases at constant pressure [kJ/(kmol.K)]

| K | $H_2$ | $N_2$ | CO | Air | $O_2$ | HCℓ | $C\ell_2$ | $H_2O$ | $CO_2$ | $SO_2$ | $SO_3$ | $CH_4$ | $C_2H_4$ | $C_2H_6$ | $NH_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 298 | 28.84 | 29.13 | 29.18 | 29.18 | 29.39 | 29.13 | 33.99 | 33.57 | 37.57 | 40.14 | 50.69 | 35.79 | 43.74 | 52.87 | 35.50 |
| 400 | 29.01 | 29.21 | 29.32 | 29.32 | 29.75 | 29.19 | 34.57 | 33.94 | 39.23 | 41.68 | 54.77 | 38.31 | 48.85 | 59.31 | 37.21 |
| 500 | 29.15 | 29.35 | 29.45 | 29.45 | 30.18 | 29.24 | 35.16 | 34.40 | 40.07 | 43.32 | 58.42 | 41.03 | 53.71 | 65.56 | 38.76 |
| 600 | 29.19 | 29.53 | 29.67 | 29.69 | 30.65 | 29.32 | 35.58 | 34.93 | 42.72 | 44.81 | 61.63 | 43.84 | 58.29 | 71.56 | 40.19 |
| 700 | 29.24 | 29.98 | 29.98 | 30.02 | 31.14 | 29.43 | 35.86 | 35.35 | 44.15 | 46.11 | 64.40 | 46.69 | 62.46 | 77.26 | 41.55 |
| 800 | 29.31 | 30.27 | 30.27 | 30.34 | 31.60 | 29.60 | 36.10 | 35.90 | 45.43 | 47.23 | 66.80 | 49.46 | 66.26 | 83.30 | 42.89 |
| 900 | 29.36 | 30.61 | 30.61 | 30.64 | 32.00 | 29.78 | 36.30 | 36.49 | 46.54 | 48.17 | 68.85 | 52.23 | 69.73 | 87.39 | 44.23 |
| 1000 | 29.46 | 30.93 | 30.93 | 30.94 | 32.37 | 30.00 | 36.45 | 37.08 | 47.56 | 49.01 | 70.27 | 54.66 | 72.91 | 91.93 | 45.56 |
| 1100 | 29.57 | 31.24 | 31.24 | 31.27 | 32.70 | 30.25 | 36.59 | 37.68 | 48.50 | 49.75 | 72.27 | 57.06 | 75.91 | 96.20 | 46.86 |
| 1200 | 29.69 | 31.56 | 31.56 | 31.56 | 33.02 | 30.49 | 36.74 | 38.29 | 49.35 | 50.43 | 73.72 | 59.43 | 78.66 | 100.00 | 48.16 |
| 1300 | 29.89 | 31.84 | 31.84 | 31.93 | 33.32 | 30.75 | 36.85 | 38.89 | 50.10 | 51.01 | 75.11 | 61.49 | 81.15 | 103.09 | 49.44 |
| 1400 | 30.07 | 32.09 | 32.09 | 32.13 | 33.60 | 31.00 | 36.94 | 39.45 | 50.82 | 51.53 | 76.36 | 63.47 | 83.51 | 107.17 | 50.71 |
| 1500 | 30.23 | 32.34 | 32.34 | 32.38 | 33.84 | | | 40.01 | 51.43 | | | | | | |
| 1600 | 30.39 | 32.58 | 32.58 | 32.61 | 34.05 | | | 40.56 | 51.99 | | | | | | |
| 1700 | 30.56 | 32.79 | 32.79 | 32.79 | 34.23 | | | 40.03 | 52.54 | | | | | | |
| 1800 | 30.75 | 32.67 | 33.00 | 33.01 | 34.40 | | | 41.47 | 53.18 | | | | | | |
| 1900 | 30.97 | 32.86 | 33.20 | 33.24 | 34.66 | | | 41.84 | 53.43 | | | | | | |
| 2000 | 31.12 | 33.03 | 33.37 | 33.41 | 34.83 | | | 42.53 | 53.74 | | | | | | |
| 2100 | 31.32 | 33.20 | 33.52 | 33.56 | 34.98 | | | 42.98 | 54.25 | | | | | | |
| 2200 | 31.48 | 33.35 | 33.70 | 33.70 | 35.12 | | | 43.41 | 54.56 | | | | | | |

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## Appendix 6A Properties of elements and inorganic compounds

| Compound | Formula | Molecular weight | Normal melting point K | Normal boiling point K | Specific gravity (at K) | Physical state at 298 K | Enthalpies kJ/kmol: Heat of formation $\Delta H_f$ | Heat of fusion $\Delta H_{fus}$ | Heat of vaporization $\Delta H_{vap}$ | Heat of solution $\Delta H_{sol}$ | Molar heat capacities kJ/(kmol · K): Of the liquid | Of the solid $A + BT + CT^2$: $A$ | $B \times 10^3$ | $C \times 10^6$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Aluminum | Al | 26.97 | 933 | 2328 | 2.70 (293) | c | 1. 0 | 10,700 | 255,400 | ... | 29.3 | 20.09 | 13.48 | 0 |
| 2. Ammonia | $NH_3$ | 17.03 | 195.5 | 239.8 | ... | g | 2. −45,900 | 5,600 | 23,400 | −34,700 | | | | |
| 3. Calcium carbonate | $CaCO_3$ | 100.09 | −CO, 1098 | ... | 2.71 (298) | c | 3. −1,207,700 | ... | ... | ... | ... | 82.46 | 49.81 | −12.89 |
| 4. Calcium chloride | $CaCl_2$ | 110.99 | 1055 | ... | 2.15 (288) | c | 4. −797,900 | 25,500 | ... | −77,900 | 103.4 | 70.74 | 16.16 | 0 |
| 5. Calcium hydroxide | $Ca(OH)_2$ | 74.10 | $-H_2O$ 853 | ... | 2.2 (293) | c | 5. −986,200 | ... | ... | −15,100 | ... | 89.58 | 0 | 0 |
| 6. Calcium oxide | CaO | 56.08 | 2843 | 3123 | 3.32 (293) | c | 6. −635,900 | 51,200 | ... | −81,600 | ... | 41.86 | 20.26 | −4.52 |
| 7. Calcium sulfate | $CaSO_4$ | 136.14 | ... | ... | 2.96 (293) | c | 7. −1,418,000 | 28,000 | ... | −18,000 | ... | 77.44 | 92.09 | −6.57 |
| 8. Carbon (amorphous) | C | 12.01 | ... | 4473 | 1.8–2.1 | ... | 8. | | | | | | | |
| 9. Carbon (diamond) | C | 12.01 | 3773 | 4473 | 3.51 (293) | c | 9. +1,900 | ... | ... | ... | ... | 9.04 | 12.81 | −5.44 |
| 10. Carbon (graphite) | C | 12.01 | 3933* | 4473 | 2.26 (293) | c | 10. 0 | 46,000 | ... | ... | ... | 11.18 | 10.97 | −4.90 |
| 11. Carbon dioxide | $CO_2$ | 44.01 | 216.6 | 194.7* | ... | g | 11. −393,700 | 8,000 | 25,200† | −19,300 | | | | |
| 12. Carbon monoxide | CO | 28.01 | 68 | 81.7 | ... | g | 12. −110,600 | 840 | 6,030 | | | | | |
| 13. Chlorine | $Cl_2$ | 70.91 | 172.2 | 238.6 | ... | g | 13. 0 | 6,400 | 20,400 | | | | | |
| 14. Copper | Cu | 63.57 | 1356 | 2868 | 8.92 (293) | c | 14. 0 | 13,000 | 304,800 | ... | 31.4 | 22.77 | 6.11 | 0 |
| 15. Helium | He | 4.00 | 1.0 | 4.3 | ... | g | 15. 0 | 42 | 84 | | | | | |
| 16. Hydrogen | $H_2$ | 2.016 | 14.0 | 20.5 | ... | g | 16. 0 | | | | | | | |
| 17. Hydrogen chloride | HCl | 36.47 | 162 | 188 | ... | g | 17. −92,300 | 2,000 | 16,200 | −74,500 | | | | |
| 18. Hydrogen sulfide | $H_2S$ | 34.08 | 190.3 | 213.6 | ... | g | 18. −20,100 | 2,400 | 18,800 | −19,300 | | | | |
| 19. Iron | Fe | 55.85 | 1808 | 3008 | 7.86 (293) | c | 19. 0 | 14,900 | 354,100 | ... | 34.1 | 17.29 | 26.71 | 0 |
| 20. Iron chloride | $FeCl_2$ | 162.22 | 555 | 588 | 2.80 (284) | c | 20. −403,500 | 86,200 | 50,400 | −134,400 | | | | |
| 21. Iron oxide | FeO | 71.85 | 1693 | ... | 5.7 (293) | c | 21. −270,400 | 32,200 | ... | ... | ... | 52.83 | 6.24 | −3.18 |
| 22. Iron oxide | $Fe_2O_3$ | 159.70 | d. 1833 | ... | 5.12 (293) | c | 22. −772,300 | ... | ... | ... | ... | 103.5 | 67.00 | −17.71 |
| 23. Magnesium chloride | $MgCl_2$ | 95.23 | 985 | 1685 | 2.33 (293) | c | 23. −634,600 | 33,900 | 136,800 | +150,400 | ... | 72.42 | 15.78 | 0 |
| 24. Magnesium sulfate | $MgSO_4$ | 120.38 | 1458 | ... | 2.66 (293) | c | 24. −1,276,500 | 14,700 | ... | +57,700 | ... | 111.8 | 0 | 0 |

## Appendix 7C Mean molar heat capacities of gases at constant pressure [kJ/(kmol · K)]

| K | $H_2$ | $N_2$ | CO | Air | $O_2$ | HCl | $Cl_2$ | $H_2O$ | $CO_2$ | $SO_2$ | $SO_3$ | $CH_4$ | $C_2H_4$ | $C_2H_6$ | $NH_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 298 | 28.84 | 29.13 | 29.18 | 29.18 | 29.39 | 29.13 | 33.99 | 33.57 | 37.17 | 40.14 | 50.69 | 35.79 | 43.74 | 52.87 | 35.50 |
| 400 | 29.01 | 29.21 | 29.32 | 29.32 | 29.75 | 29.19 | 34.57 | 33.94 | 39.23 | 41.68 | 54.77 | 38.31 | 48.85 | 59.31 | 37.21 |
| 500 | 29.15 | 29.35 | 29.45 | 29.45 | 30.18 | 29.24 | 35.16 | 34.40 | 40.07 | 43.32 | 58.42 | 41.03 | 53.71 | 65.56 | 38.76 |
| 600 | 29.19 | 29.53 | 29.67 | 29.69 | 30.65 | 29.32 | 35.58 | 34.93 | 42.72 | 44.81 | 61.63 | 43.84 | 58.29 | 71.56 | 40.19 |
| 700 | 29.24 | 29.76 | 29.98 | 30.02 | 31.14 | 29.43 | 35.86 | 35.35 | 44.15 | 46.11 | 64.40 | 46.69 | 62.46 | 77.26 | 41.55 |
| 800 | 29.31 | 30.31 | 30.27 | 30.34 | 31.59 | 29.60 | 36.10 | 35.90 | 45.43 | 47.23 | 66.80 | 49.46 | 66.26 | 83.30 | 42.89 |
| 900 | 29.36 | 30.34 | 30.61 | 30.64 | 32.00 | 29.78 | 36.30 | 36.49 | 46.54 | 48.17 | 68.85 | 52.23 | 69.73 | 87.39 | 44.23 |
| 1000 | 29.46 | 30.64 | 30.93 | 30.94 | 32.37 | 30.00 | 36.45 | 37.08 | 47.56 | 49.01 | 70.27 | 54.66 | 72.91 | 91.93 | 45.56 |
| 1100 | 29.57 | 30.93 | 31.24 | 31.27 | 32.70 | 30.25 | 36.59 | 37.68 | 48.50 | 49.75 | 72.27 | 57.06 | 75.91 | 96.20 | 46.86 |
| 1200 | 29.69 | 31.22 | 31.56 | 31.56 | 33.02 | 30.49 | 36.74 | 38.29 | 49.35 | 50.43 | 73.72 | 59.34 | 78.66 | 100.15 | 48.16 |